Synoptic Estimates of Waves and Currents via Real-Time Assimilation of In-Situ Observations

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LONG-TERM GOALS

The long-term goal of this effort is to develop an improved nearshore wave and current modeling system in order to achieve better and more detailed short-term predictive estimates of nearshore oceanographic conditions over spatial scales on the order of kilometers and time scales of the order hours to days.

OBJECTIVES

The overall objective of this particular component of the project is to support the integration of a variational data assimilation capability into the nearshore wave and current model based on the extended-Boussinesq equations of Wei *et al.* (1996). Specific objectives of this support effort are to 1. Identify improvements in model physics that are necessary for the success of the data assimilation procedure; 2. Perform a full-scale test of the data assimilation algorithm using data from a comprehensive field experiment (NCEX); 3. Explore areas where deficiencies in model physics have an impact on the success of the assimilation procedure.

APPROACH

The approach for the assimilation algorithm will be to assimilate time-series data obtained from in-situ instruments within the domain of interest into the model system in order to generate improved time-dependent boundary conditions at the model boundaries. These improved boundary conditions will then enable the model to yield better agreement between modeled and measured waves and currents during the observation period of interest and hence, an improved synoptic picture of the waves and currents throughout the domain. The development of the assimilation algorithm is being led by Dr. Dave Walker at General Dynamics (Ann Arbor) under a separate award (N00014-00-D-0114-0007).

Several outstanding issues need to be addressed in order to implement effectively the assimilation algorithm. First, operating phase-resolving models of Boussinesq-type over large domains (field scale) is computationally intensive and adding the assimilation algorithm will add significantly to the computational requirements. This leads us to a) choose a parallelized coding approach (using Fortran 77 and the Message Passing Interface) and means that b) it will be best to operate the wave model only at the minimum level of complexity necessary for the specific application. Thus, the first issue to be addressed is to determine exactly what level of complexity is necessary. For example, at the NCEX field site our approach is to begin with the somewhat simpler Boussinesq equations of Nwogu (1993) and we include only simplified parameterizations for wave breaking and wave runup. We will first test

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the accuracy of this approach in “forward mode”, i.e. driving the model at the offshore boundary and without actively assimilating in-situ observations. The model predictions in forward mode will be compared to in-situ observations from NCEX as they become available; we will concentrate on observations and predictions of the wave and current conditions offshore of the breaking point at this initial stage.

The second issue is related to the first in that in order to begin comparing results from the forward model to measurements from the NCEX experiment we will need a “wavemaker” capable of generating an arbitrary wave directional spectrum (corresponding to the offshore buoy measurements at the site). This is a non-trivial task, our approach is to work with the University of Delaware group (Jim Kirby et al.), and we will adapt their Beta-version directional wavemaker for our MPI code.

The wavemaker issue also affects the initialization of the model system when operating in “assimilation mode”. It is likely that the ability of the assimilation code to converge to a stable and improved solution will be dependent on the offshore boundary time series used to initialize the model. The accuracy necessary for this initial condition is unknown; hence, we are incorporating a wavemaker capable of reproducing a measured spectrum as opposed to an approximate version (e.g. a TMA spectrum). In addition, it may be necessary to calculate the initial boundary condition time series along both lateral boundaries as well as the offshore boundary. This will involve accounting for the depth variations along the lateral boundaries in the wavemaker condition.

Finally, the model results in assimilation mode may be sensitive to the wave breaking and runup parameterizations, especially when surf zone data is used for assimilation. The wave breaking and runup processes are highly nonlinear and it is unclear how well surf zone information will be transmitted through the breaker line back to the boundaries during the assimilation process. Hence, in this support effort we will further investigate the abilities of present wave breaking parameterizations in defining the locations and persistence of wave breaking on a wave-by-wave basis.

WORK COMPLETED

Jim Kirby (U. Delaware) has provided us with the Beta-version directional wavemaker for the FUNWAVE code and this has been adapted for our parallelized version of the Boussinesq code. In the present version we use a line source method instead of a 2D source and the wavemaker is does not allow waves to pass through the offshore boundary. This reduces the number of nodes (and hence computational time) used for the source function. However, there is a cost since waves reflected from the beach will eventually re-reflect from the wavemaker. However, at this stage the effects are negligible since the domain is large.

In order to begin direct comparisons between FUNWAVE model predictions of wave breaking (initial break point, breaking duration, breaking frequency, etc.) with observations, we performed a brief laboratory experiment in the Large Wave Flume at OSU. The analysis of the video observations is ongoing and being performed by a self-funded graduate student (Eileen Crawford).

At present, we are awaiting delivery of the parallel version of the code from D. Walker in order to merge the new wavemaker. Last we spoke, the transition of the code from a Linux Beowulf platform to a Sun Sparc platform has led to some unexpected stability problems.

RESULTS

A parallelized version of the fully nonlinear Boussinesq model including the various additional parameterizations (FUNWAVE; Wei et al., 1996; Kennedy et al., 2000; Chen et al., 2000) does not presently exist. Hence, we are adding additional components to the base parallel code (based on Nwogu, 1993) as they become necessary. Several deficiencies in the existing pre-existing parallelized version of the model system have been identified. The numerical filtering scheme was inadequate such that for long runs numerical noise began to dominate the solution. D. Walker has recently implemented a new numerical filter and has demonstrated improved stability for monochromatic, normally incident wave conditions.

I am presently implementing a wavemaker that is capable of generating an arbitrary directional spectrum at the offshore boundaries. The next step will be to investigate extending the wavemaker along the lateral boundaries.

Initial qualitative comparisons of model predictions of wave breaking to video observations suggest that the modeled wave breaking is more discrete i.e. narrowly distributed both in time and along the wave profile than video observations of turbulent white water would suggest. A related result was recently noted by Kirby et al. (2003), in model/data comparisons of surf zone currents in the shear wave band. Specifically, they found that the modeled low frequency shear wave spectrum was more narrow banded than is indicated in field observations. Hence, it appears that the existing wave breaking parameterizations may not accurately reproduce the frequency content of the wave breaking dissipation that is the driving force of low-frequency motions in the surf zone. We are actively trying to quantify this discrepancy further.

This will allow evaluation of forward model parameterizations of wave breaking by comparing model predictions of spatial and temporal wave breaking patterns with video observations (both SandyDuck data and AROSS data from Duck) in order to identify any improvements in model physics necessary for the success of the assimilation procedure.

IMPACT/APPLICATIONS

The results of the proposed program will provide the capability of monitoring near-shore waves and currents over large scales with greater accuracy, and allow the timely use of information from in-situ sensors. There is a great potential for improving nearshore wave/current model predictions using these types of data assimilation techniques. The applications for these model systems include providing an ongoing synoptic view of a field experiment in progress to determining in a timely manner the conditions on a denied beach. The potential for providing a much more accurate synoptic view of the hydrodynamic conditions also will be a powerful tool for interrogating the near-shore hydrodynamics on beaches with high spatial variability.

RELATED PROJECTS

This project is part of the ONR Nearshore Canyon Experiment (http://science.whoi.edu/users/pvlab/NCEX) and strongly linked with the work of D. Walker under Coastal Geosciences Award N00014-00-D-0114-0007.

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